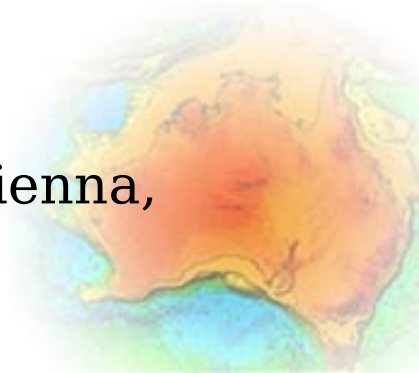
Australian Government

Geoscience Australia

Selection of the stable radio sources for the ICRF-2

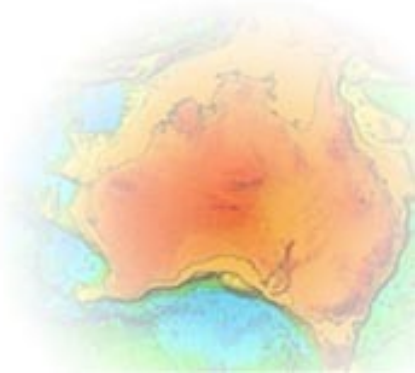
O. Titov

ICRF-2 Working Group Meeting, 12 April, 2007 Vienna, Austria



Selection criteria (to be discussed)

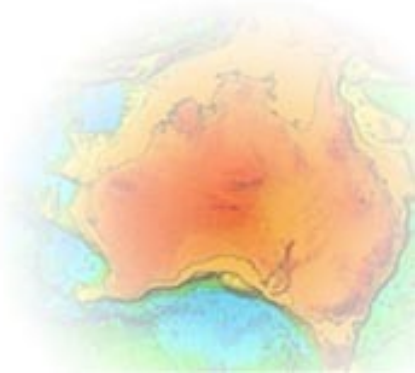
1. positional stability (time series)
2. structure delay
3. apparent proper motion
4. red shift



Positional stability (time series)

Three options are to be considered

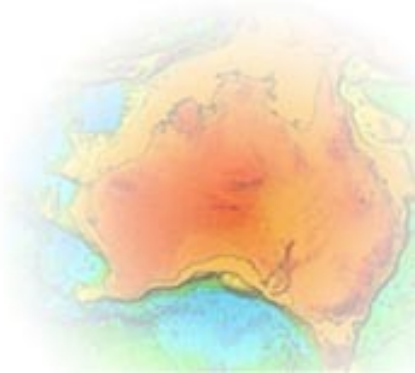
- Yearly spaced time series
- Weekly/monthly spaced time series
- Daily estimates



	Pros	Contras
Yearly	Evenly-spaced time series; Sufficient number of obs for each point;	Intra-annual variations are not counted; Outliers due to the ‘network’ are not counted
Weekly/monthly	Evenly-spaced time series, though some points would be missing	Some high-frequency effects are averaged Some points are not accurate due to low number of obs in a session
Daily	Variations of all frequency ranges are available;	Unevenly-spaced time series; Some points are not accurate due to low number of obs in a session

Positional stability criteria for time series

- wrms
- Allan variance
- linear drift
- All these criteria are not perfect if a radio source’s positional instability is fit by a piece-wise linear function

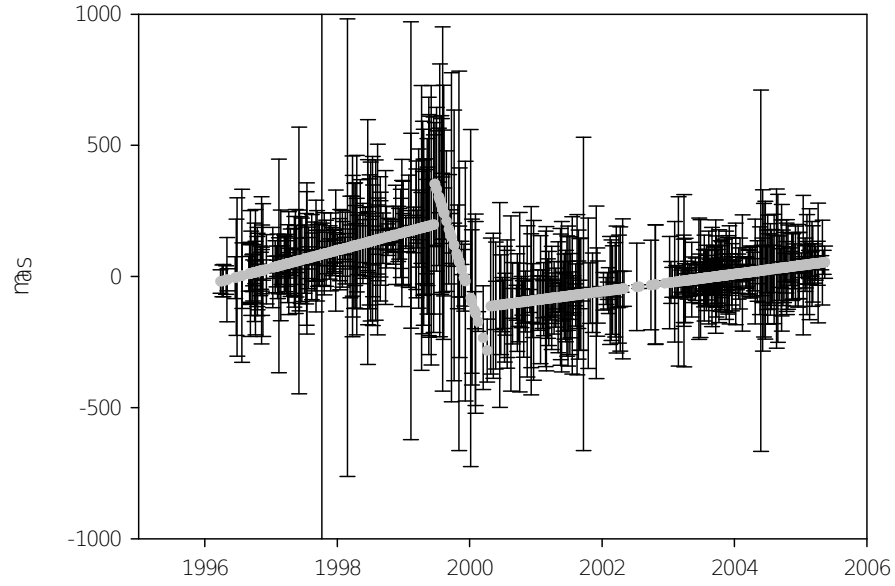


	Pros	Contras
wrms	Effectively measures the white noise level	Not effective if actual variations do not to model “linear trend + white noise”
Allan variance	Recognizes different stochastic processes	Not effective for linear drift or piece-wise function
Linear drift	Clearly visible Effective for measure of long-term instabilities	If the actual time series are made of a set of line segments the linear drift estimate would be biased

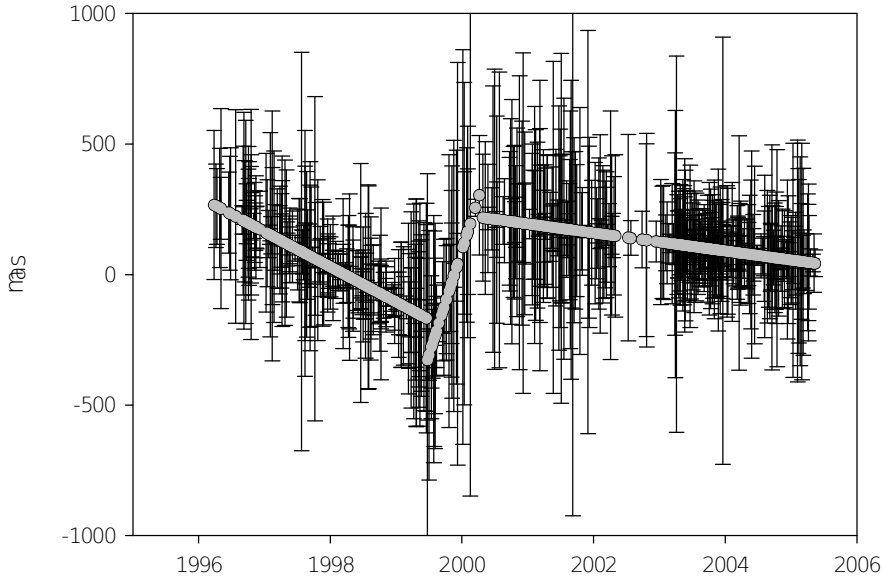
Time series

1739+522

α



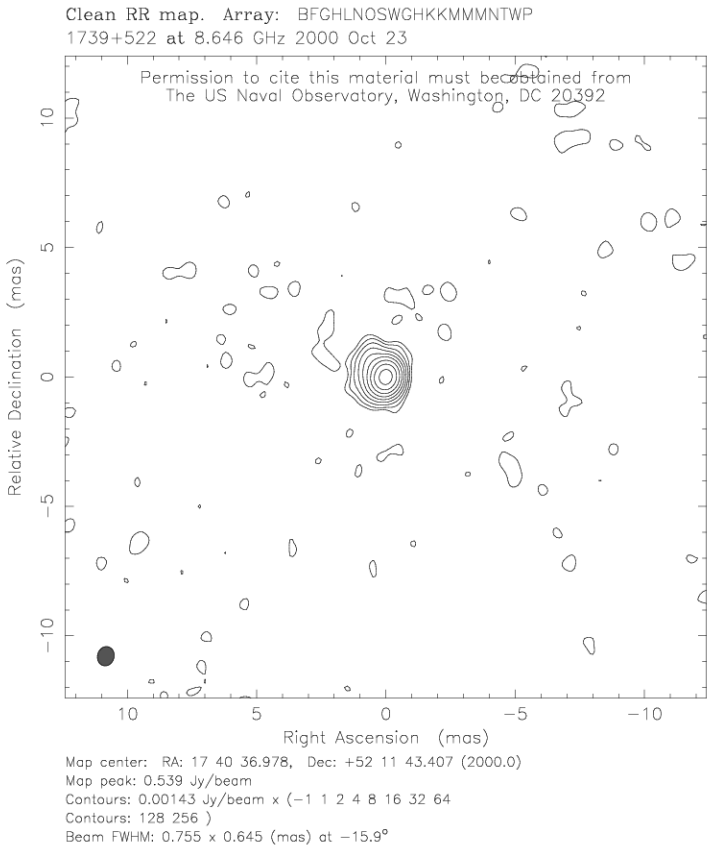
δ



1739+522

Extremely high positional motion is detected between 1999.5 and 2000.3 - about 1.1 mas/year

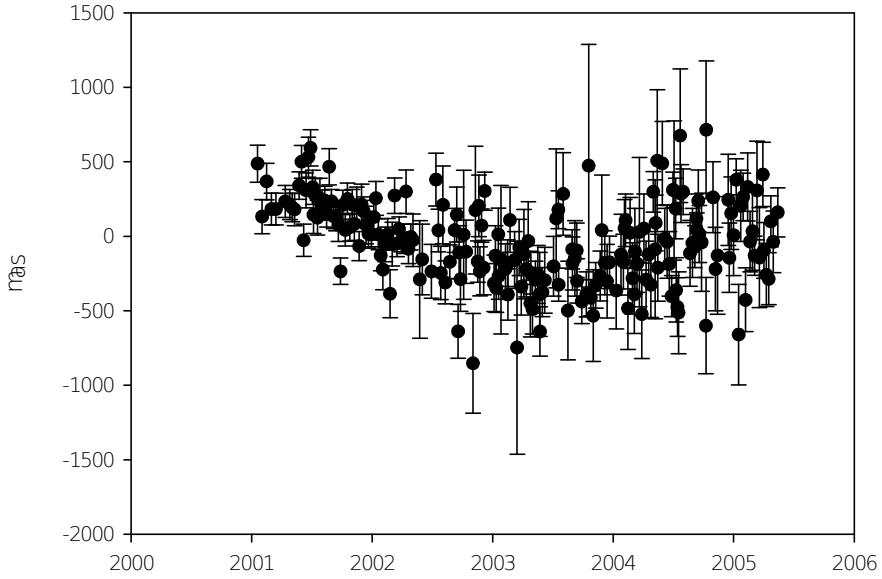
No astrophysical evidence of instability was found (RRFID)


Clean RR map. Array: BFGHLNOSWGHKKMMMNTWP
1739+522 at 8.646 GHz 2000 Oct 23
Permission to cite this material must be obtained from
The US Naval Observatory, Washington, DC 20392
Relative Declination (mas)
10
5
0
−5
−10
Right Ascension (mas)
10
5
0
−5
−10
Map center: RA: 17 40 36.978, Dec: +52 11 43.407 (2000.0)
Map peak: 0.539 Jy/beam
Contours: 0.00143 Jy/beam x (−1 1 2 4 8 16 32 64
Contours: 128 256)
Beam FWHM: 0.755 x 0.645 (mas) at −15.9°

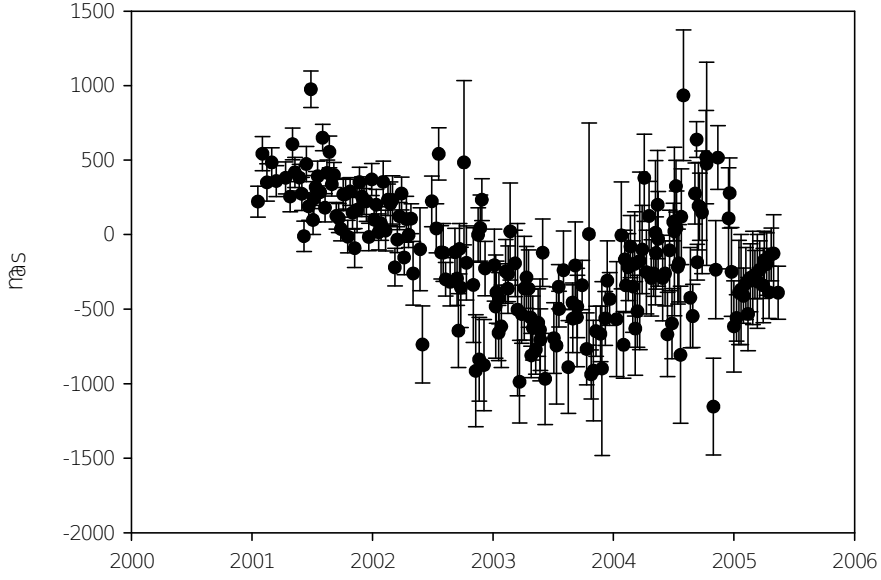
Time series

2201+315

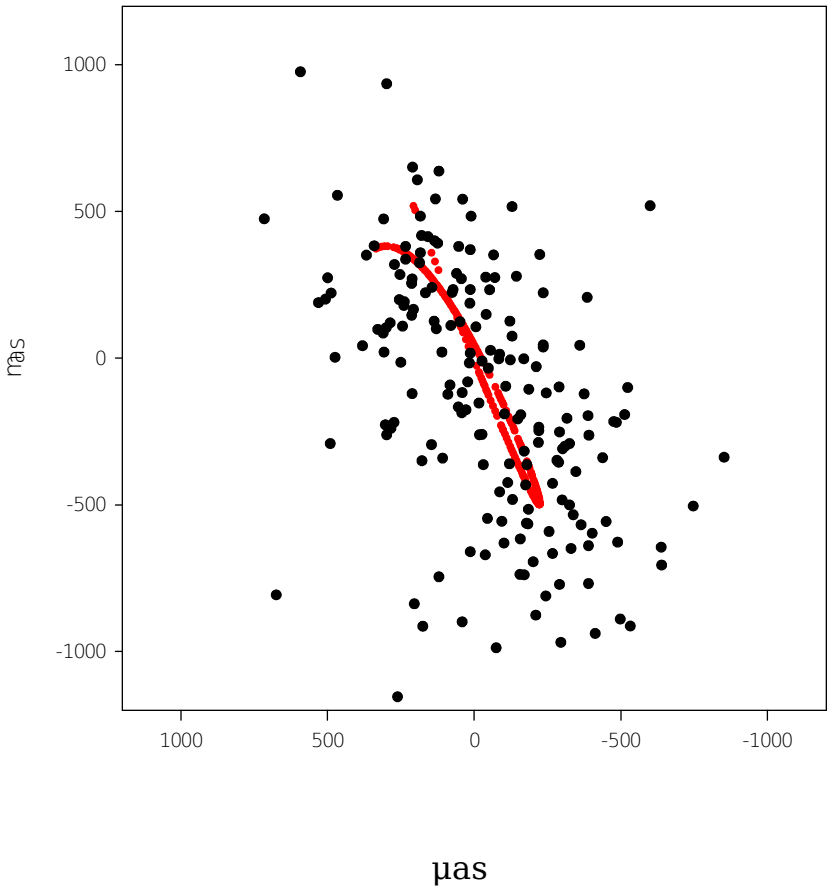
α

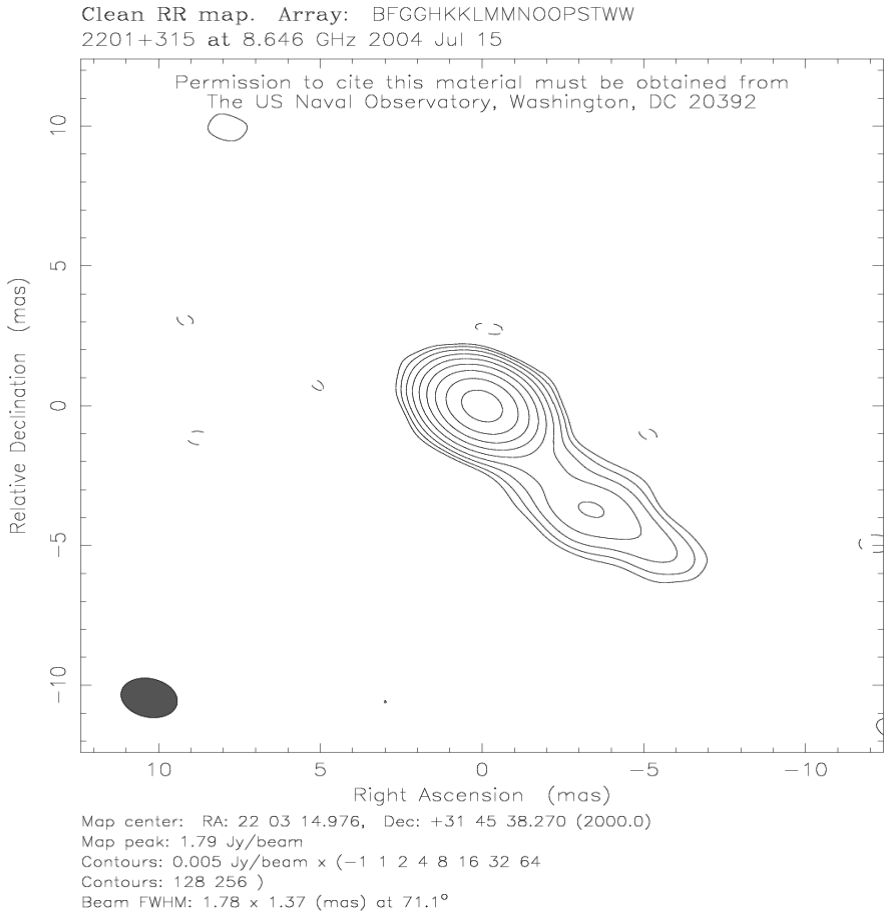


δ



2201+315 (2001-2005)




Clean RR map. Array: BFGGHKKLMMNOOPSTWW
2201+315 at 8.646 GHz 2004 Jul 15
Permission to cite this material must be obtained from
The US Naval Observatory, Washington, DC 20392
Relative Declination (mas)
10
5
0
−5
−10
10
5
0
−5
−10
Right Ascension (mas)
Map center: RA: 22 03 14.976, Dec: +31 45 38.270 (2000.0)
Map peak: 1.79 Jy/beam
Contours: 0.005 Jy/beam x (−1 1 2 4 8 16 32 64
Contours: 128 256)
Beam FWHM: 1.78 x 1.37 (mas) at 71.1°

2201+315

For 2201+315 the radio brightness centroid moves forward and backward.

Black dots show the 2201+315 daily positional estimates and red loop – approximation of the trajectory on the sky plane. The positional angle (left plot) is close to that measured by astrophysical methods (right plot) and available at the USNO RRFID database (Fey, private communication)

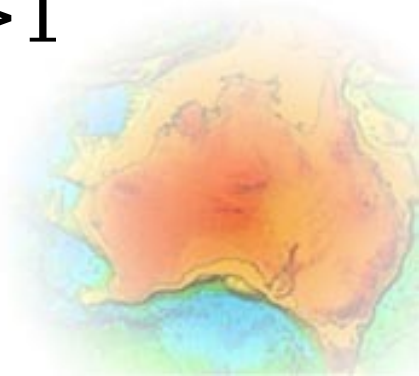
The linear trend parameters for three radio sources are compared on the next page table

Astrometry vs. astrophysics

Source	Kellerman et al. (2004)		VLBI time series		
	α (μas/year)	δ (μas/year)	period of time	α (μas/year)	δ (μas/year)
4C39.25	67 +/- 2	2 +/- 2	1995 - 2003	64.8 +/- 1.7	-
2145+067	-23 +/- 2	14 +/- 2	1993.0- 2005.9	-29.8 +/- 3.9	-
2201+315	120 +/- 14	-280 +/- 14	2001.0 – 2003.5	-248 +/- 24	-400 +/- 30

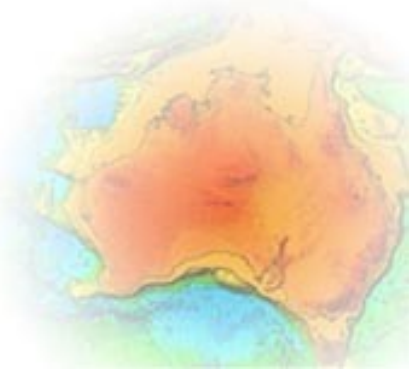
Piece-wise linear function

- Time series of radio source positions are driven by very fast motion of ultra (super?) relativistic jets
- Piece-wise linear function is effective for this kind of variation
- The length of segment is from several months to several years
- Linear motion can be pretty fast: >1 mas/year



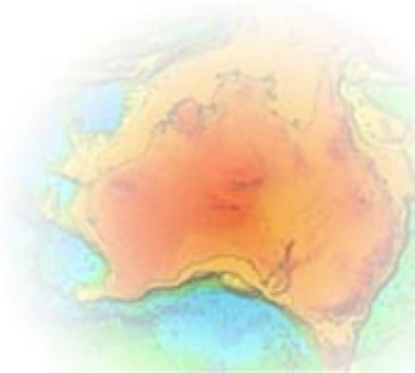
Piece-wise linear function

- Effective for many sources
- Astrophysical foundation - the motion of ultra (super?) relativistic jet causes variations of intrinsic structure
- Different linear drift on different segments



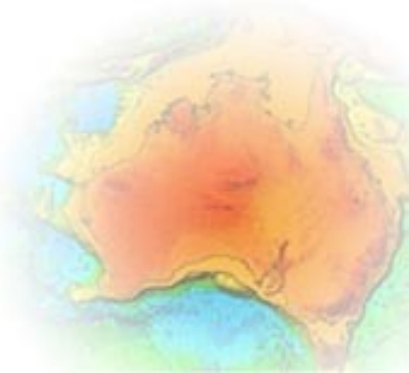
Piece-wise linear function (problems)

- Unfortunately, all criteria mentioned above are not effective, if a radio source’s position time series fits to a piece-wise linear function;
- One has to build up time series of daily estimates to figure the start and end of each segment



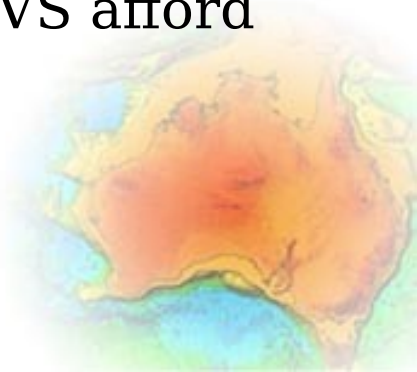
Personal impression

- **Calculation of the time series of the daily positions for all radio sources looks inevitable!**

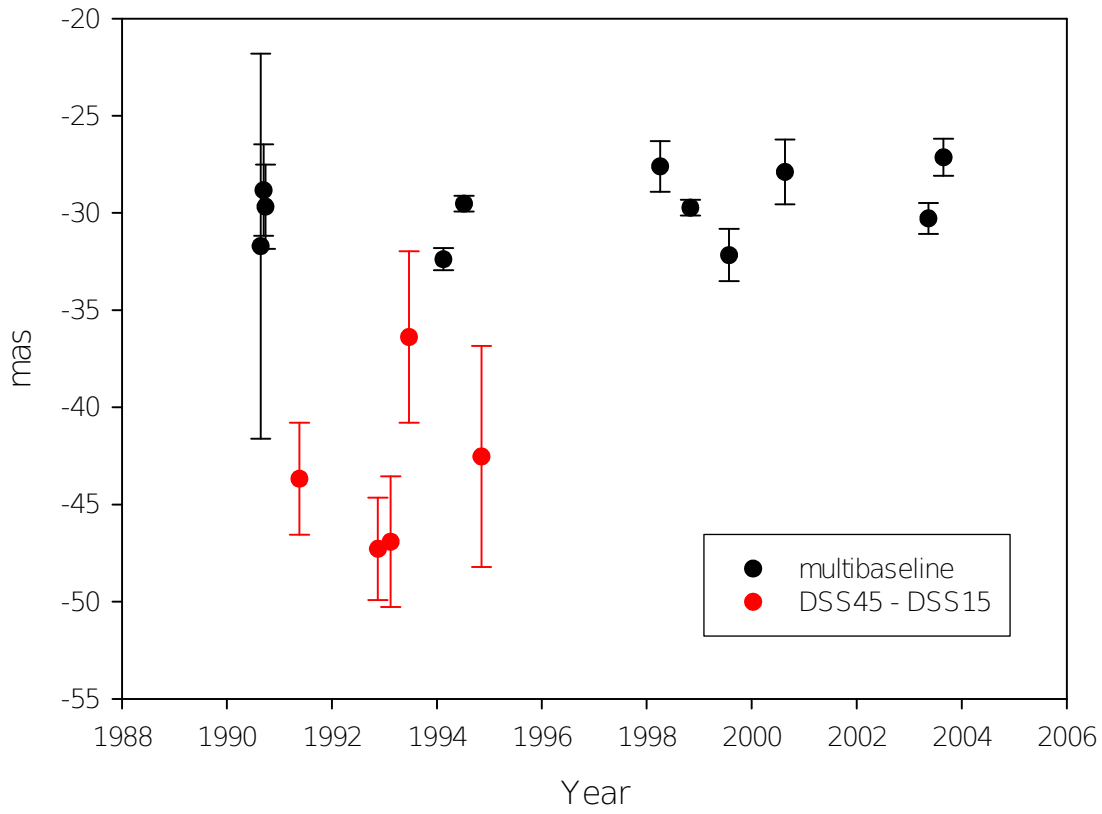


Structure delay

- Based on radio source structure – reflects a real change of the radio brightness centroid position
- The structure delay (structure index) should be variable due to intrinsic structure change. These variations have been recently detected (Charlot, private communication)
- Monitoring of structure delay is very useful, unfortunately, it would take sizable resources
- The networks consisting of many VLBI sites (10 or more) should be used several times per year (monthly or bi-monthly) to monitor the fast changes of structure delay. That's a very disputable point. **Question:** Can IVS afford that?



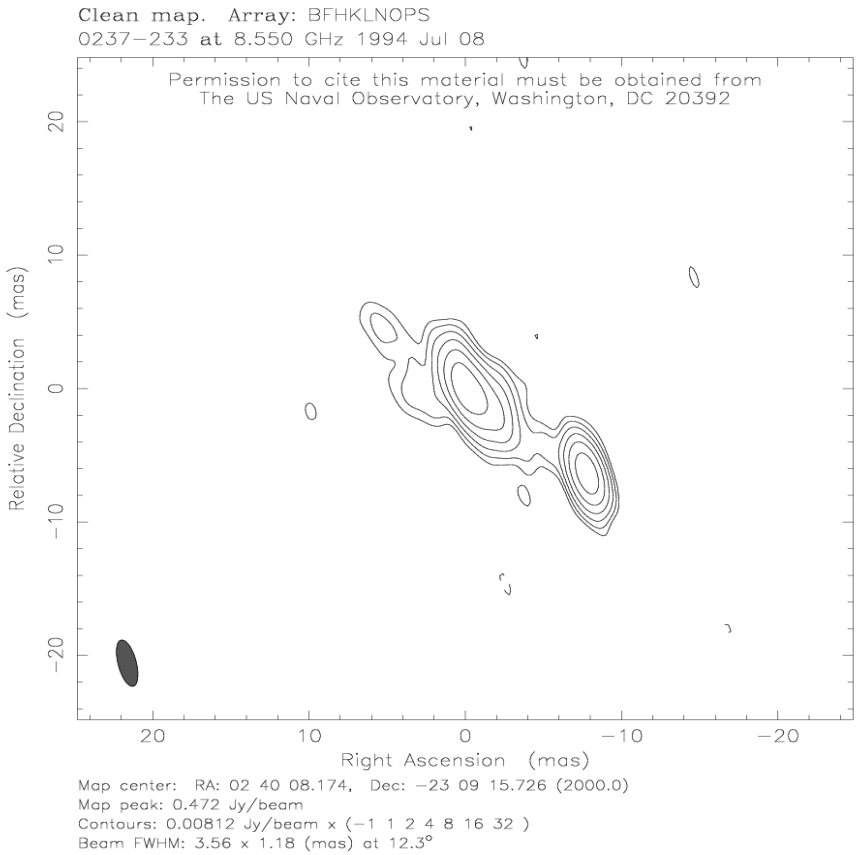
0237-233
declination



Offset between two subsets of estimates

~12 mas in declination

0237-233


Clean map. Array: BFHKLNOPS
0237−233 at 8.550 GHz 1994 Jul 08
Permission to cite this material must be obtained from
The US Naval Observatory, Washington, DC 20392
Relative Declination (mas)
20
10
0
−10
−20
Right Ascension (mas)
Map center: RA: 02 40 08.174, Dec: −23 09 15.726 (2000.0)
Map peak: 0.472 Jy/beam
Contours: 0.00812 Jy/beam x (−1 1 2 4 8 16 32)
Beam FWHM: 3.56 x 1.18 (mas) at 12.3°

Offset ~12 mas

Median structure delay

238 ps (~2 mas)

(Fey, Charlot; 1997)

Maximum structure delay

2422 ps (~20 mas)

(Fey, Charlot; 1997)

0237-233

Averaged yearly estimates of the 0237-233 positions did not demonstrate any kind of instabilities. That's why this source was classified as 'stable' (Feissel-Vernier, 2003)

However, daily estimates being split into two sets that are segregated by network show an offset of 10-12 mas in both components. Astrophysical imaging data (RRFID; Fey, private communication) confirmed the highly extended structure of 0237-233 accompanied by the large structure delay. Again, no astrophysical evidence of instability was found.

Structure delay

This extremely large positional offset between two different networks as for 0237-233 is a rare situation.

However, smaller positional offsets (<0.5 mas) induced by different networks would be common for extended radio sources, although no instabilities were detected.

It could result in extra noise for the extended radio sources with respect to the compact radio sources.

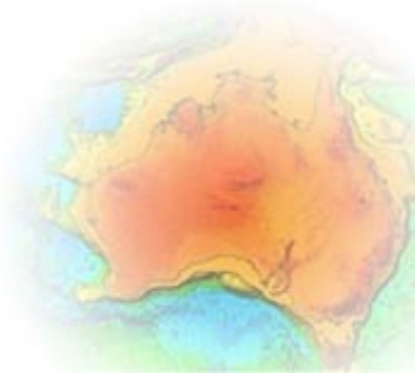
Structure delay

Very dense regional networks (VLBA, Europe) can provide the high-accuracy positions of the extended radio sources that differ from the positions measured by globally distributed network. The reason is in different resolution ~λ/D. For these regional networks the D is used to be several times less than for a global network

Question: Should we use data from the sessions limited by regional networks?

Apparent proper motion

- Estimated directly as global parameters (linear drift)
- Sufficient number of sessions is required
- Do not reflect real change in positions
- **Question:** Should we use them somehow?



Red shift

- The radio sources with higher red shift show smaller apparent proper motions (MacMillan, 2003). Some of the observed radio sources have $z<0.005$ and would be even more problematic than others.
- **Question:** Should there be cutoff for the ‘close’ radio sources, say, with $z<0.3$, ‘on default’ to get rid of potential danger for future?